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JULY, 1936

No. 4

ANNUAL REPORT
OF THE
OHIO ACADEMY OF SCIENCE
Forty-sixth Meeting
1936

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PUBLICATION COMMITTEE

E. L. RICE, *Chairman*

C. G. SHATZER

R. V. BANGHAM

THE OHIO ACADEMY OF SCIENCE

Organized 1891

Incorporated 1892

Affiliated with the American Association for the Advancement of Science

OFFICERS AND COMMITTEES FOR 1936-1937

President

CHARLES A. DOAN

Vice-Presidents

- | | |
|-----------------------------------|--------------------------------------|
| A. Zoology: A. W. LINDSEY | E. Psychology: GARRY C. MYERS |
| B. Botany: CLAUDE E. O'NEAL | F. Physics and Astronomy: G. E. OWEN |
| C. Geology: FRED FOREMAN | G. Geography: REUEL B. FROST |
| D. Medical Sciences: R. A. KNOUFF | H. Chemistry: C. E. BOORD |
- (Vice A. P. MATHEWS, declined)

Secretary

WILLIAM H. ALEXANDER

Treasurer

A. E. WALLER

Executive Committee

Ex-Officio: CHARLES A. DOAN, WM. H. ALEXANDER, A. E. WALLER

Elective: WALTER H. BUCHER, H. H. M. BOWMAN

Board of Trustees

- | | |
|---|------|
| HERBERT OSBORN, <i>Chairman</i> , term expires..... | 1938 |
| GEORGE D. HUBBARD, term expires..... | 1937 |
| WILLIAM LLOYD EVANS, term expires..... | 1939 |

Committee on Publications

- | | |
|---|------|
| EDWARD L. RICE, <i>Chairman</i> , term expires..... | 1937 |
| C. G. SHATZER, term expires..... | 1937 |
| R. V. BANGHAM, term expires..... | 1937 |

Library Committee

- MRS. ETHEL M. MILLER, *Chairman*,
In charge of Academy Exchanges and Publications
- | | |
|-----------------------------------|------|
| L. B. WALTON, term expires..... | 1937 |
| F. O. GROVE, term expires..... | 1938 |
| W. H. SHIDELER, term expires..... | 1939 |

Committee on State Parks and Conservation

- | | |
|---|------|
| EDWARD S. THOMAS, <i>Chairman</i> , term expires..... | 1937 |
| HERBERT OSBORN, term expires..... | 1937 |
| WILBER E. STOUT, term expires..... | 1937 |
| G. W. CONREY, term expires..... | 1938 |
| E. L. WICKLIFF, term expires..... | 1938 |
| ARTHUR T. EVANS, term expires..... | 1938 |
| EMERY R. HAYHURST, term expires..... | 1939 |
| EDMUND SECREST, term expires..... | 1939 |
| L. E. HICKS, term expires..... | 1939 |

Academy Representatives on the Joint Administrative Board, Ohio Journal of Science

- | | |
|-----------------------------------|------|
| EDWARD L. RICE, term expires..... | 1937 |
| C. G. SHATZER, term expires..... | 1938 |

Nominating Committee for 1937

- | | |
|----------------------|----------------------|
| A. DAVID F. MILLER | E. JAMES R. PATRICK |
| B. GLENN W. BLAYDES | F. CHARLES W. JARVIS |
| C. GRACE ANN STEWART | G. GUY-HAROLD SMITH |
| D. CHARLES A. DOAN | H. K. G. A. BUSCH |

REPORT OF THE FORTY-SIXTH ANNUAL MEETING OF THE OHIO ACADEMY OF SCIENCE

WILLIAM H. ALEXANDER,
Secretary

INTRODUCTORY

One hundred and seventy-three members registered at the Forty-sixth Annual Meeting of the Ohio Academy of Science held at the University of Toledo, Toledo, Ohio, on April 10 and 11, 1936; forty-one new members were elected and fifteen were raised to the rank of Fellow in the Academy.

There were two short business sessions of the Academy, some twelve or thirteen sectional meetings and a half dozen joint meetings of two or more sections, including the *Ohio Physics Club*, which, according to the custom of the past few years, met with the *Section of Physics and Astronomy*. The tendency toward joint meetings of the sections was quite evident from the printed program and was amply justified by the results, it appears. The general scientific sessions of the Academy were reduced to a minimum—only one. At this one meeting the Academy had the rare privilege of hearing an address abundantly illustrated by lantern slides and movie films on "Endocrine Factors in Sexual Reactions of Amphibia," by Dr. Roberts Rugh, of Hunter College, New York City. The Presidential Address on "*The Concept of Natural Law in Geology*," by President Bucher, was of a higher order and was most favorably received and commented upon.

Another feature of notable value was the "*Symposium on Virus Diseases*" conducted under the auspices of the Sections of Medical Sciences and Zoology. These discussions were led by men of eminent talent and of recognized authority and aroused much enthusiasm and profitable thought and debate.

Aside from the election of officers and committeemen, the items of business of general interest to the Academy transacted at this meeting were, first, the practical approval of the Academy of a recommendation from the Executive Committee to amend the Constitution and By-Laws so as to make the membership committee a *standing committee of the Academy* through which to carry on a continuous membership drive, and second, a decision to fall in line with the newly-adopted policy of the American Association for the Advancement of Science to grant

funds for research only. The Board of Trustees of the Research Fund has been asked to prepare definite instructions for submitting requests for aid in research problems. A third item of interest was the authorizing of the incoming president to appoint a committee of five to take into consideration during the year the matter of a suitable observance four years hence of the fiftieth anniversary of the organization of the Academy and to bring in definite recommendations at the next annual meeting.

MINUTES OF THE BUSINESS SESSIONS

First Session: April 10, 1936

The first business session was called to order by the President at 9:30 A. M. in the Doermann Theater, University of Toledo, with a quorum present. The President announced the appointment of the following special committees:

On Membership—K. G. A. Busch, Eugene Van Cleef, and Samuel Allen.

On Resolutions—Frederick C. Waite.

On Necrology—James P. Porter.

The reports of the Secretary and Treasurer were read, accepted and filed. By vote of the Academy, the Secretary cast a written ballot for the eight current vice-presidents to constitute a nominating committee for 1937.

The report of the Executive Committee was read by the Secretary, formally received and ordered filed.

Upon motion unanimously passed the Secretary was directed to prepare the necessary amendments to the Constitution and By-Laws to make the membership committee permanent and submit same to the next annual meeting of the Academy, this motion to serve as notice of the proposed changes.

Adjourned to meet at 8:30 A. M. tomorrow.

Second Session: April 11, 1936

The adjourned business session was called to order by President Bucher at 8:30 A. M. with a quorum present.

The report of the Trustees of the Research Fund was read by the President in the absence of the Chairman of the Board, Dr. Herbert Osborn. The Trustees expressed the hope that

any member in need of financial assistance in connection with a research problem would not hesitate to let it be known even though the amount available is small.

As usual, the Library Committee, through its chairman, Mrs. Ethel M. Miller, presented an interesting report which was received with enthusiasm and ordered filed with a vote of thanks to Mrs. Miller.

For the Committee on State Parks and Conservation, Mr. E. S. Thomas, its chairman, made a very complete and highly entertaining report which was received with appreciation and ordered filed.

The Secretary then read the report of the Committee on the Election of Fellows as published elsewhere in these Proceedings.

For the Membership Committee Dr. K. G. A. Bush reported having received 41 applications for membership in the Academy and as all were in due form and accompanied by one year's dues the committee recommended their election to full membership. Report received and recommendation approved.

The report of the Joint Administrative Board, Ohio Journal of Science, prepared by C. G. Shatzer and E. L. Rice, was read by Prof. L. H. Snyder, editor of the Journal, formally received and ordered filed.

Dr. A. E. Waller, representative of the Academy on the Save Outdoor Ohio Council, reported for that organization. His report appears elsewhere in these Proceedings.

For the Nominating Committee, Prof. Robert S. McEwen, chairman, made the following report:

For President.....CHARLES A. DOAN

For Vice-Presidents—

- A. Zoology.....A. W. LINDSEY
- B. Botany.....CLAUDE E. O'NEAL
- C. Geology.....FRED FOREMAN
- D. Medical Sciences.....R. A. KNOUFF
- E. Psychology.....GARRY C. MYERS
- F. Physics and Astronomy.....G. E. OWEN
- G. Geography.....REUEL B. FROST
- H. Chemistry.....ALBERT P. MATHEWS

For Secretary.....WILLIAM H. ALEXANDER

For Treasurer.....A. E. WALLER

For Executive Committee.....

{
W. H. BUCHER
H. H. M. BOWMAN

<i>For Publications Committee and Administrative Board.....</i>	{ E. L. RICE C. G. SHATZER R. V. BANGHAM
<i>For Board of Trustees.....</i>	WILLIAM L. EVANS
<i>For Library Committee.....</i>	W. H. SHIDELER
<i>For State Parks and Conservation.....</i>	{ E. R. HAYHURST EDMUND SECREST L. E. HICKS

The report was received and motion duly passed instructing the Secretary to cast the unanimous vote of the Academy for the nominees mentioned.

Following the report of the Nominating Committee, the attention of the Academy was called to the recommendation from the Executive Committee to the effect that some action be taken at this meeting looking toward a suitable observance of the fiftieth anniversary of the founding of the Academy and after some discussion, Dr. F. C. Waite made the following motion:

“That the incoming President appoint a preliminary committee of five on plans for the celebration and that this committee be charged to make a definite report of plans at the meeting next year.”

The Secretary then asked if the Academy wished to select a representative on the Council of the American Association for the Advancement of Science at the Atlantic City meeting next December or to express its wish as to time and place of the next meeting. Upon motion duly passed these matters were referred to the Executive Committee with power but not before Dr. R. V. Bangham, on behalf of the College of Wooster, expressed the hope that the Academy would meet in Wooster next year.

Adjourned at 9:25 A. M.

THE SCIENTIFIC SESSIONS

GENERAL AND SECTIONAL

The following is a list of the addresses and papers presented at the general and sectional meetings of the Academy as reported to the secretary, viz.:

1. THE PRESIDENTIAL ADDRESS: The Concept of Natural Law in Geology.....WALTER H. BUCHER
2. THE INVITATION ADDRESS: Endocrine Factors in Sexual Reactions of Amphibia.....DR. ROBERTS RUGH
3. Notes on Ohio Ladybird Beetles (*Coccinellidae*).....WILLIAM C. STEHR
4. A Useful Method of Labeling Geological and Paleontological Specimens,
MARY AUTEN

5. A Study of Certain Groups of the Genus *Thamnottetix*, DWIGHT M. DELONG
6. A Study of the Male Genital Characters of the Genus *Draeculacephala* (Homoptera, Cicadellidae), DWIGHT M. DELONG AND RALPH H. DAVIDSON
7. Initial Temperature Effect upon the Rate of Differentiation of Whitefish Embryos..... JOHN W. PRICE
8. Anomalies in Whitefish Embryos Induced by Extreme Temperatures, WALTER M. STOUT
9. The Respiratory Mechanism of *Thyone briareus*..... ROBERT A. BUDINGTON
10. Cytological Observations on the Relation Between the Acini and the Islets of Langerhans in the Rat Pancreas..... S. D. NEILSEN
11. Barnacles of Hawaii..... J. PAUL VISSCHER
12. Responses of Chick Gonads to Gonadotropic Hormones... W. R. BRENNEMAN
13. Chromatophore Studies in the Vermillion-spotted Newt, KENNETH L. KELLEY
14. Early Development of the Swim-bladder in *Hemichromis bimaculata*, ROBERT S. MCEWEN
15. A Revision of the Planarian Genus *Phagocata*..... JAMES A. MILLER
16. Reduction of Janus Green in *Limnodrilus Claparedianus*. JAMES A. MILLER
17. Constant Temperature Record of Surface Water in Lake Erie and its Relation to Dissolved Oxygen and Carbon Dioxide, FREDERICK H. KRECKER
18. Seasonal Changes in the Size and Activity of Thyroid Glands in Wild Birds..... S. CHARLES KENDEIGH
19. Relationships between Blood Sugar and Torpidity in Certain Hibernating Animals..... JOHN M. CONDRIN
20. Activity Rhythms in Goldfish..... WILLIAM KIEFFER
21. Experimental Rearing of Whitefish in Ohio State Fish Farms in 1935, T. H. LANGLOIS
22. The Use of Paraldehyde and Benzyl Alcohol Mixture as an Anesthetic for Laboratory Animals..... W. R. BRENNEMAN AND EDWARD LEDERMAN
23. Merriam's Life Zones and the Distribution of Ohio Orthoptera, EDWARD S. THOMAS
24. Wildlife Sanctuaries Sponsored by the Ohio Academy of Science in Southern Ohio..... FLOYD B. CHAPMAN
25. A Suggested Quail Management Program in Ohio, LUTHER L. BAUMGARTNER
26. On Bird Migration "Waves"..... LYNDS JONES
27. Returns from Fish Tagged in Ohio..... E. L. WICKLIFF
28. Artificial Lakes in Ohio..... LEE S. ROACH
29. The Bird Population of a 65 Acre Tract of Beech-Maple Forest Near Cleveland..... ARTHUR B. WILLIAMS
30. Low Dams and Their Effect on Stream Conditions..... LEE S. ROACH
31. Suggested Modifications for Stream Cleanup Projects.... E. L. WICKLIFF
32. Applications of Pollen Analysis in Semi-arid Climates.... PAUL B. SEARS
33. Progress of Barberry Eradication in Ohio..... HARRY ATWOOD
34. The Pathologic Races of Wheat Stem Rust in Ohio, W. G. STOVER AND HARRY ATWOOD
33. Barberry Seedling Survival at Maumee, Ohio..... W. G. STOVER
36. Southern Appalachian Flora in Jackson County..... LESLIE L. PONTIUS
37. The Alkaline Raised Bogs of Ohio and Indiana..... ROBERT B. GORDON
38. Report on the State Herbarium and New Records of Ohio Vascular Plants..... JOHN H. SCHAFFNER
39. The Behavior of Chlorophyll in the Green Leaf..... ONDESS L. INMAN
40. Methods of Obtaining Evidence of Achievement of Student in Relation to Various Objectives of Botany Teaching..... CLARK W. HORTON
41. Somatic Development with Reference to the "Multinucleate Phase" and "Phragmosphere" Formation..... R. T. WAREHAM
42. The Status of *Arundo bambos* L..... F. A. MCCLURE
43. Conidial Variation in Some Imperfect Fungi..... CONST. J. ALEXOPOULOS
44. A Note on Epiphytic Algae on the Roots of an Orchid. H. H. M. BOWMAN
45. Apomixis in Iris..... A. E. WALLER
46. Some Structural Changes in Soy Bean Plants Grown from Seeds Irradiated with Soft X-Rays..... THEO. P. LONG AND H. KERSTEN
47. Champaign's Guardian of Biological History, (Presented by title), MARGARET B. CHURCH

48. Rare Stylolites.....PARIS B. STOCKDALE
49. Portersville Member of the Conemaugh Formation in Muskingum
County, Ohio.....WILSON M. LAIRD
50. Some Allegheny Cephalopods from Eastern Ohio...MYRON T. STURGEON
51. *Triarthrus eatoni* in the Eden of Ohio.....HARRY J. KLEPSE
52. Some Aspects of Acidizing Oil Wells.....P. E. FITSGERALD
53. Outline of the Section of Geology Spring Field Trip....GRACE A. STEWART
54. Some Geological Relationships of the Soils of Great Britain, G. W. CONREY
55. Silting in the Muskingum College Lake.....G. ROBERT HALL
56. Observation of Wave Action along the Shores of Lake Erie,
WILLIAM H. GOULD
57. The Glacial Beaches in Lucas County.....J. ERNEST CARMAN
58. A Reclassification of the Paleozoic Systems of Michigan...G. M. EHLERS
59. Some Economic Aspects of Chert in Mineral Aggregates, HERBERT F. KRIEGE
60. Lewis Hills Overthrust, Western Newfoundland.....JOHN R. COOPER
61. A Preliminary Report on the Igneous Intrusions in the Vicinity of
Monterey and Hightown, Highland County, Virginia....FRED FOREMAN
62. Permian-Carboniferous Boundary in Ohio.....WILLARD BERRY
63. Foundation Exploration for the Muskingum Watershed Conservancy
Dams.....HENRY G. MARTIN

SYMPOSIUM ON VIRUS DISEASES

64. The Nature of Viruses with Special Reference to Plant Viruses, by JORGEN
M. BIRKELAND, PH. D., Assistant Professor of Bacteriology, Department
of Bacteriology, Ohio State University.
65. The Use of the Foetus as an Experimental Animal for Virus Studies, by
ORAM C. WOOLPERT, PH. D., M. D., Assistant Professor of Bacteriology,
Department of Bacteriology, Ohio State University.
66. The Cultivation of, and Immunological and Clinical Studies with, the Virus
of Lymphogranuloma Inguinale, by JOSEPH T. TAMURA, PH. D., Depart-
ment of Bacteriology and Hygiene, University of Cincinnati.
67. Factors of Resistance and Immunity in Poliomyelitis, by N. PAUL HUDSON,
PH. D., M. D., Professor and Chairman of the Department of Bacteriology,
Ohio State University, EDWIN H. LENNETTE and FRANCIS B. GORDON,
Department of Hygiene and Bacteriology, University of Chicago.
68. Epidemiologic Considerations in the Field of Virus Diseases with Special
Reference to the Common Cold and Influenza, by J. A. DOULL, M. D.,
D. P. H., Professor and Director of the Department of Hygiene and Public
Health, Western Reserve University School of Medicine.
69. Locating the Basal Age on the Stanford Revision of the Binet-Simon
Scale by Means of the Vocabulary Test.....W. E. MCCLURE
70. The Effect of Point of View in a Ranking Test.....J. J. SMITH
71. The Relation of Length of Material and Other Factors to Exposure Time
in the Perception and Memory for Visual Forms,
WILLIAM C. SCHWARZBEK
72. Further Study of the Childhood Environmental Determinants of
Adolescent Personality.....ROSS STAGNER
73. Abuse of the Genetic Viewpoint.....H. B. ENGLISH
74. An Attempt to Measure the Effectiveness of White Space in an Advertise-
ment on the Basis of Actual Sales.....MELVIN RIGGS
75. Effect of Various Incentive Conditions on Work Out-put....J. S. KOUNIN
76. The Breakdown of a Discrimination Habit and Its Bearing upon
Reminiscence.....AMOS C. ANDERSON
77. The Influence of the Figure-Ground Relation in Memorizing Visual
Forms.....OTIS D. KNIGHT
78. Brain Potentials in Children and Adults.....DONALD B. LINDSEY
79. A New Approach to the Study of Traffic Behavior.....S. E. HAVEN
80. A New Type of Timing Apparatus and its Application in the Training of
Runners.....S. M. HOWARTH and B. M. DAVIS
81. The Influence of Note-taking upon the Comprehension of Certain Text-
book Materials.....C. D. MATTHEWS
82. Age Differences in Productivity: "Best Books".....H. C. LEHMAN
83. Size Constancy in Visual Objects.....BEVERLY E. HOLIDAY

84. Sources of Moral Judgments of Under-Privileged Children,
GORDON HENDRICKSON
85. A Critical Evaluation of Some Class-Room Learning Problems,
GARRY C. MEYERS
86. Identification of Harmonics at Radio Frequencies..... RICHARD HOWE
87. Interpretation of Star Counts in Obscure Regions..... FREEMAN D. MILLER
88. Absorption Spectra of Some of the Simpler Porphyrins,
V. M. ALBERS AND H. V. KNORR
89. Electrical Contact..... T. H. OSGOOD
90. Further Studies with Negative Hydrogen Ions,
PAUL F. DARBY AND WILLARD H. BENNETT
91. Sharpness and Speed of Photographic Lenses, J. A. BING AND C. O. DELUNG
92. The Ultra-Violet Absorption Spectrum of Nitrogen..... J. J. HOPEFIELD
93. Time Measurements on Photographic Shutters... L. E. KOESTER AND I. SEFF
94. Study of Electrolytic Dissociation of KHSO_4 by Raman Effect,
DONALD M. CAMERON AND WAVE H. SHAFFER

JOINT MEETING WITH OHIO PHYSICS CLUB AND CHEMISTRY SECTION

95. Internal vs. External Symmetry in Crystals..... F. C. BLAKE
96. Fluorescence and Photo-decomposition of Chlorophyll *a* and *b* under
Atmospheres of O_2 , CO_2 and N_2 H. V. KNORR AND V. M. ALBERS
97. Some Remarks on Waves and Corpuscles..... A. LANDE
98. A System of Isotopes..... HAROLD B. LAW
99. The Nature of the Metallic State..... W. CONRAD FERNELIUS
100. Some Properties of Deuterium Oxide..... JOHN S. RICHARDSON
101. Artificial Radioactivity..... HERRICK JOHNSTON

JOINT EDUCATIONAL PROGRAM WITH OHIO PHYSICS CLUB AND CHEMISTRY SECTION

102. Projects in Chemistry III. Projects in the Teaching of Chemistry
Course..... K. G. BUSCH
103. Series and Parallel Resonance Circuit for Lecture..... RAY LLOYD
104. Comparison of Vacuum Tubes for Use as Direct Current Amplifiers,
GEO. H. GABUS
105. Stimulation of Student Interest in Physics..... JOHN MESCHER
106. Discovering Laws in the Elementary Laboratory..... H. P. KNAUSS
107. Laboratory Apparatus..... DON SMITH
108. Two Simple Classroom Experiments..... JOHN P. KARBLER
109. New Free Fall Apparatus..... NOLAN BEST
110. The Luminosity of Stars of High Axial Rotation..... J. A. HYNEK
111. X-Ray Energy Levels..... S. J. M. ALLEN
112. Aerial Phytography and Map Revision..... MAJOR FRED L. SMITH
113. The Westerville, Ohio, Area: An Interpretation of Field Data,
JOHN H. GARLAND
114. The Functional Pattern of Barberton, an Industrial Suburb of Akron,
Ohio..... JAMES R. BECK
115. The Evaluation of Soil Deterioration and Improvement in a Land Use
Program..... G. W. CONREY
116. Geographic Aspects of Coal Cargoes from Toledo..... WALTER G. LEZIUS
117. Finnish Population Movement in Ohio..... EUGENE VAN CLEEF
118. Physical Influences on Economic Pressures in Ohio... KYLE W. ARMSTRONG
119. Physical Factors Affecting Land Use in Central Massachusetts,
GUILBERT R. GRAHAM
120. The Resettlement Project of the Matanuska Valley in 1935,
C. C. HUNTINGTON
121. Schott's Natural Regions of the Oceans: A Review.... PRESTON E. JAMES
122. The Delusion of the Colonial Argument..... W. R. MCCONNELL
123. Can Germany be Self-sufficient?..... CLARENCE HESKETT
124. Early Geographic Adjustments in the Wellington Settlement, New
Zealand..... WILFRED G. RICHARDS
125. Recent Trends in the Foreign Trade of Japan..... DANIEL R. BERGMARK

126. The Precipitation of Barium Sulfate in Alkaline Solutions,
CLYDE A. HUTCHISON AND H. V. MOYER
127. The Determination of Atmospheric Pollution. A Demonstration,
PHILIP R. FEHLANDT
128. Gasoline Explosion Investigation,
ALBERT R. MORRISON AND JAMES R. WITHROW
129. New Synthetic Porphyrins.....PAUL ROTHMUND
130. Thermodynamic Investigation of Flash Evaporation of Potassium
Sulphate Liquors from Polyhalite. Accuracy of International Critical
Tables Data on Heat of Formation of Potassium Sulphate Solutions,
JOSEPH PATRICK CREAGH AND JAMES R. WITHROW
131. The Value of Chemistry in Determining the Mineral Constituents of
Our Common Rocks.....WILBER STOUT

JOINT MEETING WITH THE SECTION OF PHYSICS AND
ASTRONOMY AND THE OHIO PHYSICS CLUB

132. Joint Education Program with Section of Physics and Astronomy and
the Ohio Physics Club.
133. Trip of Inspection by the Chemistry Section to the Owens-Illinois Glass
Research Laboratory.
134. This recently built laboratory is made entirely of glass blocks, is
insulated with glass wool, and has no windows. This trip should be
of great interest to all chemists and also others interested in science.

REPORTS

Report of the Secretary

TOLEDO, OHIO, April 10, 1936.

To the Ohio Academy of Science:

The general duties of a secretary are well known and therefore need not be reviewed at this time. Details too numerous to mention, a rehearsal of which would be inexcusably tedious and might even "bore you to extinction;" we will therefore content ourselves with a few high spots, reserving for ourselves the Congressional privilege of extending our remarks for the record!

The secretary's work does not end with the adjournment of the annual meeting; the proceedings must be prepared for filing and publication; newly elected members, fellows and officers must be notified, and a suitable report for publication in *Science* must be prepared. All these things we did to the best of our ability and as promptly as possible. See *Science* of May 27, 1935.

We represented the Academy as best we could on the Council of the American Association for the Advancement of Science at St. Louis, Mo., last December; also at the Academy Conference, being elected and now serving as the President of this latter organization. We secured for the Academy a cash allowance of \$124.00 for the year 1935, on the ground that the Academy was not in a position to avail itself of the grant for research owing to the short notice of the change in policy on the part of the A. A. A. S.

As chairman of the program committee we have co-operated cheerfully and most delightfully with the vice-presidents in the collection of the program material and the making of the program which you have in your possession. The results of the committee's effort speak for themselves. We have also co-operated in an effort to secure new members for the Academy and we wish once again to emphasize this very essential matter. The old stand-bys are leaving us; recruits must be secured!

And now for about the thirteenth time, your secretary wishes to record his very high appreciation of the fine co-operation he has had from the members and officers of the Academy in his efforts to discharge the duties of his office; the associations have been delightful and the memory of these will be fragrant in the months and years to come. This is our greatest reward!

Respectfully submitted,

WILLIAM H. ALEXANDER,
Secretary.

Report accepted and ordered filed.

Report of the Treasurer

RECEIPTS

Cash on hand, January 1, 1935.....	\$ 594.64
Receipts from the Sale of Publications.....	\$ 55.60
Received from A. A. A. S.....	124.00
Interest on Bonds.....	479.76
Dues from Members, Back Dues Collected.....	503.50
Total Receipts.....	1,237.27
Total.....	\$1,831.91

DISBURSEMENTS

Expense to Executive Committee Meetings.....	\$ 7.80
Spahr & Glenn Co., Printers.....	101.71
Ohio Journal of Science.....	1,230.01
Membership, Save Out Door Ohio Council.....	8.00
Postage for Secretary's and Treasurer's Office.....	22.50
Clerical Help, Secretary's and Treasurer's Office.....	77.71
Expenses of Vice-Presidents.....	35.81
Safety Deposit Box.....	3.30
Program, Committee Meeting, Expenses.....	12.63
Secretary's Honorarium.....	100.00
Flowers for 1935 Annual Dinner.....	2.00
Tickets for 1935 Annual Dinner.....	2.32
Stenographic Report of 1935 Business Meeting.....	10.40
Auditing 1934 Report.....	17.50
Returned Check and Bank Charges.....	4.63
Total Disbursements.....	\$1,636.32

Total Receipts.....	\$1,831.91
Total Disbursements.....	1,636.32
Balance.....	\$ 195.59

Respectfully submitted,

A. E. WALLER,
Treasurer.

*Report of Auditor**To the Ohio Academy of Science:*

I have audited the report of the Treasurer of the Ohio Academy of Science for the year 1935-36 and have found the following statements to be true:

Cash on hand, January 1, 1935.....	\$ 594.64
Add: Receipts for the year 1935-36.....	1,237.27
	<hr/>
	\$1,831.91
LESS: Disbursements for the year 1935-36.....	1,636.32
	<hr/>
Cash Balance, January 16, 1936.....	\$ 195.59
Balance in Huntington National Bank, January 16, 1936.....	\$ 195.59
LESS: Outstanding Checks.....	(None)
	<hr/>
Cash Balance, January 16, 1936.....	\$ 195.59

OHIO ACADEMY OF SCIENCE BALANCE SHEET

As of January 16, 1936

ASSETS

CURRENT ASSETS:

Cash.....	\$ 195.59
Bonds—3% Cons. Federal Land Bank (listed at purchase price).....	1,290.25
Research Fund (Schedule I).....	1,923.27
	<hr/>
	\$3,409.11

LIABILITIES AND NET WORTH

NET WORTH:

Surplus.....	\$3,409.11
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RESEARCH FUND

SCHEDULE I.

Cash Balance, January 1, 1935.....	\$ 200.40
Add: Receipts for Year 1935-36 (Dividends and Interest).....	86.25
	<hr/>
	\$ 286.65
LESS: Disbursements for year 1935-36.	
Lorain Urban Survey and Bank Charges.....	100.88
	<hr/>
Cash Balance, January 1, 1935.....	\$ 185.77
Bank Balance, January 1, 1935.....	\$ 185.77
LESS: Outstanding Checks.....	(None)
	<hr/>
Balance, January 1, 1935.....	\$ 185.77
Cash Balance.....	\$ 185.77
Bonds, 5% (listed as at purchase price).....	1,300.00
BancOhio Stock, 25 shares.....	437.50
	<hr/>
Total Research Fund.....	\$1,923.27

I certify that the above statements are, in my opinion, true and correct and correctly set forth the results of the operations of the Ohio Academy of Science for the year January 1, 1935, to January 1, 1936.

Respectfully submitted,

DELBER KINSEL,
Fraternity Auditor.

Report of the Trustees of the Research Fund

December 19, 1936.

*Mr. W. H. Alexander, Secretary,
Ohio Academy of Science.*

DEAR MR. ALEXANDER:—I submit herewith statement of the Academy Research Fund as of present date and, as there are no commitments or anticipated changes before the end of the month, present the account for the annual audit in this form. As I expect to leave Columbus before the end of the year and as I may not be in attendance at the spring meeting of the Academy this account may be submitted as the annual report, although I may wish to make an additional statement at that time.

SUMMARY OF CREDITS

Balance in Checking Account January 1, 1935.....	\$200.40
Receipts from Interest and Dividend Payments.....	86.25
Total.....	\$286.65

DISBURSEMENTS

Grant to R. B. Frost toward Lorain Urban Survey.....	\$100.00
Service Charges, Ohio National Bank.....	.88
Balance in Checking Account, Ohio National Bank.....	185.77
Total.....	\$286.65

STATEMENT OF INVESTED ASSETS

Bonds (listed as at purchase price), 5% Income.....	\$1,300.00
25 Shares BancOhio Stock (listed at purchase price).....	437.50
Total.....	\$1,737.50

Receipts from our bonds are now at the rate of 5% and the latest information I have is that the BancOhio stock is quoted at above the price we paid and we receive quarterly dividends regularly.

Our securities are deposited for safe keeping and the checking account is carried by the Ohio National Bank, 167 South High Street, Columbus, where confirmation of these figures may be obtained for the audit. Mr. Kenneth T. Whitaker, who has looked after the Academy finances since Dr. Mendenhall was in charge of the Research Funds, may be consulted for ready attention to audit enquiries.

Respectfully submitted,

HERBERT OSBORN,
Chairman, Research Fund.

NOTE.—If you will give your auditor a note certifying his authority to examine the deposits at Ohio National Bank, I am sure he will find ready attention.

H. O.

Report of the Executive Committee

(By the Secretary)

TOLEDO, OHIO, April 10, 1936.

To the Ohio Academy of Science:

The Executive Committee held three meetings during the year with all members present: One on December 7, 1935, one on January 18, 1936, and the third, last evening at the Secor Hotel in Toledo, Ohio. At the first meeting, there were present by invitation Dr. Herbert Osborn, chairman of the board of trustees of the Research Fund; Dr. E. N. Transeau, representing the Ohio State University on the Administrative Board, Ohio Journal of Science; Dr. L. H. Snyder, editor of the Ohio Journal of Science; and Dr. B. S. Meyer, business manager of the Ohio Journal of Science.

The primary purpose of this meeting was to consider certain financial matters in connection with the Ohio Journal of Science. After a full, frank statement of facts by the four gentlemen mentioned and after ample, free and frank discussion by the Committee, it appearing that a real crisis had developed in the financial affairs of the Ohio Journal of Science, the following motion was unanimously passed by the Executive Committee, viz.:

"That the Treasurer be authorized and directed to pay out of the reserve fund the sum of \$700.00 into the fund of the Ohio Journal of Science, \$450.00 of this amount to meet bills now due and \$250.00 to pay for the next issue of the Journal."

The Treasurer reported a reserve fund of some \$1,700.00. He was instructed by the Committee to invest the balance in U. S. Treasury Certificates.

At this meeting it was unanimously decided to accept the invitation of the University of Toledo to hold the 46th annual meeting within its walls.

The question of inviting the Michigan Academy of Science to meet with the Ohio Academy at Toledo was considered favorably and the Secretary was asked to look into the feasibility of such a joint meeting, if not this year, then next.

The Secretary was selected to represent the Academy on the Council of the American Association for the Advancement of Science and at the Academy Conference of the A. A. A. S.

At the second meeting the Secretary made a partial report of his actions as representative of the Academy at the St. Louis meeting of the A. A. A. S., the chief item being the securing of a cash allowance of \$124.00 instead of funds for research only. The Secretary was elected President of the Academy Conference.

In view of this rather fundamental change in the financial arrangements between the Association and the Academy the Committee felt that action should be taken to advise the membership, especially those thinking of making application for research funds, that all such applications must be in the hands of the Secretary or Chairman of the Board of Trustees not later than the annual meeting of the year in which the

solicited funds are to be used. A suitable form on which to make application for said funds is to be prepared indicating in a general way the information desired by the Academy from those applying for the funds.

The matter of delinquent dues was freely though sympathetically discussed, the discussion culminating in a request that the Treasurer send a tactful letter at once to all delinquents requesting them to indicate their wishes or intentions regarding back dues, assuring them of the Academy's willingness to accept any reasonable adjustment of same.

The question of a membership campaign was raised and the committee went on record as favorable to same and to this end it was suggested that provision be made in the Constitution or By-Laws for a standing membership committee.

A third meeting was held last evening at the New Secor Hotel, Toledo, Ohio, with all members present except the President, who was not feeling well and asked to be excused. As the result of the deliberations at this third meeting the following recommendations are made to the Academy:

1. That the necessary changes be made in the Constitution and By-Laws to provide for a permanent committee on membership.

2. That action be inaugurated at this meeting looking toward a suitable observance of the Fiftieth Anniversary of the organization of the Academy four years hence and to this end the committee suggests the appointment of a special committee of ways and means, committees, etc., to make report with recommendations at the next annual meeting of the Academy.

3. That the Board of Trustees be asked to prepare a suitable form for use in applying for research funds.

Respectfully submitted,

WILLIAM H. ALEXANDER,
Secretary.

Report accepted and ordered filed.

Report of the Library Committee

COLUMBUS, OHIO, April 10, 1936.

To the Ohio Academy of Science:

The report of the chairman of this committee for last year stated that a systematic check was then being made upon the exchanges to ascertain whether they were being received regularly at the Ohio State University library, as it had been several years since this had been done, but that no report could be given at that time. The results were just what one would expect. Most of the exchanges are coming regularly; a few had taken the name of the University Library off their mailing lists but were willing to replace it when the matter was called to their attention, and some were such that it seemed desirable for one reason or another to drop them from our mailing list. One name was transferred from the subscription list of the Ohio Journal of Science to the

exchange list as this organization has presented valuable bound books and serials to the Ohio Academy of Science for years but yet has been purchasing its copy of the Ohio Journal of Science. Fourteen exchanges were dropped and seven new ones secured. The number is now 375. As many of them send more than one title on exchange the number of periodicals and serials which are received in this way is between five and six hundred with a value of a thousand to twelve hundred dollars.

Routine work has been carried on as usual, such as claiming exchanges that failed to arrive at the proper time, changing addresses on the mailing list, adding new names and removing a few. A little more reference work than usual has been done at the request of a few of the Ohio Academy of Science members. The chairman of this library committee is very glad to be called upon for such library work as it is possible for her to do. No guarantee is made that the results will be entirely successful but the assurance is given that every possible effort will be made to secure the desired information.

The sales of publications amounted to \$50.05, which was a substantial increase over the sum of \$32.30 for the preceding year. The number of sales for each year remained the same, twenty-six, but the number of papers sold increased from 50 in 1934 to 88 in 1935. One sale of a complete set of the forty Annual Reports and all but five of the twenty-one Special Papers, amounting to \$23.70, made a good addition to the total sales. This set was purchased by Kent State College last April. Another nearly complete set was purchased this year by the Toledo Public Library. This made a good beginning for the 1936 sales and its amount of \$26.30 will appear in next year's report. Only four sales were made to places outside of our own state.

The "Batrachians and Reptiles of Ohio" gained first place in popularity this year with the "Fishes of Ohio" next. The two papers which tied for first place last year fell to fourth place this year, showing how variable the demand is from year to year.

During the year the sum of \$55.60 has been given to the Treasurer of the Academy. This included a balance of \$6.05 on the 1934 sales and \$49.55 on the sales for 1935. One bill for fifty cents is still outstanding. A paper was sold to a certain department of the Ohio State University and it will unquestionably be paid for when the unusual financial conditions now existing at the University are remedied.

The sum of \$30.09 still remains in the name of the Ohio Academy of Science in the Buckeye State Building and Loan Company. This could be withdrawn as the company is now paying on stock accounts at the rate of twenty-five dollars a month, but as it was not drawn out before the first of the year it does not appear on the Treasurer's report.

Continuing the policy of last year no formal financial statement is being given in this report, but it has been duly made and is on file for the purpose of record.

Respectfully submitted,

ETHEL MELSHEIMER MILLER,
Chairman.

*Report of the Joint Administrative Board of the
Ohio Journal of Science*

COLUMBUS, OHIO, April 10, 1936.

To the Ohio Academy of Science:

A meeting of the Joint Administrative Board was called together at 4:15 P. M. on November 16, 1935, by Chairman Rice. Present were all members of the Administrative Board, the Editor and the Business Manager of the Journal. The Business Manager presented a statement of the present financial situation of the Journal which was followed by a prolonged discussion by members of the Board.

Motion carried that the Administrative Board of the Journal approach the Executive Committee of the Ohio Academy of Science, explain to them the present financial difficulty of the Journal and request (1) payment of the Journal's share of the Ohio Academy of Science dues for the current year to date, drawing if necessary upon the reserve fund of the Academy for this payment, and (2) advance \$250.00 of the 1936 payment of the Academy in order to help defray cost of publishing the November issue of the Journal and thus avoid the present deficit in the Journal's funds due to a delay in the payment of the second half of the 1935 University grant to the Journal resulting from the Governor's vetoes.

The meeting adjourned at 5:15 P. M.

A second meeting was held on April 10, 1936. Present were Messrs. Rice, Transeau, Shatzer and Snyder. Chairman Rice presided. The Business Manager's report was presented, as follows:

THE OHIO JOURNAL OF SCIENCE

FISCAL YEAR 1935

RECEIPTS

Balance from 1934.....	\$ 317.32
University Grant.....	375.00
Ohio Academy of Science.....	600.00
Ohio Academy of Science—Proceedings, 1935.....	143.55
Ohio Academy of Science Research Fund (for paper by R. B. Frost).....	100.00
R. B. Frost, for Printing Special Paper.....	75.00
Ohio State Chapter Sigma Xi—Symposium Number.....	266.81
Subscriptions.....	85.25
Sale of Individual Copies and Volumes.....	67.50
Authors Payments for Plates and Publication Out of Order.....	80.46

\$2,110.89

EXPENDITURES

Spahr & Glenn Co., First Five Numbers, Volume 35.....	\$1,377.52
Bucher Engraving Co.....	448.90
Postal Charges.....	122.41
Envelopes.....	32.50
Clerical Assistance.....	10.60
Refund on Subscription.....	2.00
Bank Charges.....	1.23

\$1,995.16

Balance on hand February 29, 1935, Huntington National Bank..... 115.73

\$2,110.89

As of present date the bill for the November, 1935, number of the Journal, amounting to \$212.90, is still unpaid. All other 1935 bills are paid.

The report was accepted and placed on file. The present financial status of the Journal resulting from the Governor's vetoes was discussed. Since it appeared that the University payments would eventually be made, a motion prevailed that the Journal continue normal publication for the time being, at least.

Respectfully submitted,

B. S. MEYER, *Secretary,*
Joint Administrative Board of
the Ohio Journal of Science.

Report of the Save Outdoor Ohio Committee

COLUMBUS, OHIO, April 11, 1936.

To the Ohio Academy of Science:

The reorganization of the Save Outdoor Ohio Council was completed in time to align its activity with the present interest in conservation which both State and Federal Government agencies are showing. The new attitude toward conservation on government's part may be said to be widespread rather than deep. If this public vaccination with conservation is to take, public education in biology applied to human affairs is needed and badly needed. For it is plain that since conservation means different things to different men, the expenditures of enormous sums have often been at cross purposes. For example, stream clean up, a W. P. A. project, for which the Federal Government allotted one million, eight hundred thousand dollars, was quickly shown to be destructive to plant and animal life along the banks and to the plants and animals of the stream. Even worse, it is a contributing factor to water erosion in flood periods. With the advice of members of the Save Outdoor Ohio Council and the State Conservation Division the program was somewhat improved. It was not stopped entirely, of course. However, the great point was gained that the advice of the Conservation Division was given some consideration.

The plan of beginning education in conservation early is being forwarded by the Save Outdoor Ohio Council and the Division of Conservation. Just how far this will go cannot be predicted. The use of any material is optional with the schools. However, there is available from W. P. A. funds forty-six thousand dollars for materials to schools, scout troops, clubs, etc. It might be suggested that here is a chance for the members of the Ohio Academy of Science to co-operate more fully with the Save Outdoor Ohio Council and to see that really conservative practices are discussed. There has been a total reversal of judgment with respect to "vermin" which included some of the hawks and other predatory birds. There is probably a better appraisal of "weeds" which may include plant life suited to stop the erosion of top-soil layers.

The success of the Save Outdoor Ohio Council in an advisory

capacity is purely to be what we make of it. The more co-operation that is offered the better it will work. A meeting held November 22, 1935, giving an opportunity to hear a number of papers on different aspects of conservation was well attended and well received.

We have continued and expect to continue our membership in the Council. This entitles us as a committee to one vote in the Council. Actually our co-operation is much closer, as many Academy members are active in the Council as an examination of the above list of speakers serves to show.

Respectfully submitted,

A. E. WALLER,
Representative.

Report of Committee on Election of Fellows

COLUMBUS, OHIO, April 11, 1936.

To the Ohio Academy of Science:

The following members were elected to Fellowship in the Academy:

CLYDE STEWART ADAMS
DONALD JOYCE BORROR
RICHARD BRADFIELD
KARL G. A. BUSCH
W. STORRS COLE
RALPH HOWARD DAVIDSON
WILLIS CONARD FERNELIUS
MARGARET FULFORD

JESSE R. HARROD
EDWIN ELMORE JACOBS
JOSEF NISSLEY KNULL
WILLIAM A. MANUEL
JOHN ALDEN MILLER
NICHOLAS MOGENDORFF
PAUL W. K. ROTHMUND

Respectfully submitted,

W. H. ALEXANDER,
Secretary.

Report of the Trustees of the Research Fund

April 11, 1936.

To the Ohio Academy of Science:

During the past year your trustees have allowed one grant of one hundred dollars and the additions as of December 31st were \$85.25, which left in checking account \$185.77, which with additions since audit will allow something over \$200.00 available for grants or investment. The following summary shows the condition of the fund at January 1, 1936.

RECEIPTS

Balance in Checking Account, January 1, 1935.....	\$200.40
Receipts from Interest and Dividend Payments.....	86.25
Total.....	\$286.65

DISBURSEMENTS

Grant to R. B. Frost toward Lorain Urban Survey.....	\$100.00
Service Charge, Ohio National Bank.....	.88
Balance in Checking Account, Ohio National Bank.....	185.77
Total.....	\$286.65

STATEMENT OF INVESTED ASSETS

Bonds (listed at purchase price).....	\$1,300.00
25 Shares BancOhio Stock (at cost).....	437.50
Total.....	\$1,737.50

In case the plan of the A. A. A. S. to have its grant to the Academy available for research projects it will be desirable to have approved projects in view and your Trustees will welcome suggestions. Also additions to the Research Fund from any source will be most welcome as we feel that there will be ample opportunity to use the fund to advantage.

Respectfully submitted,

GEO. D. HUBBARD,
ALPHEUS W. SMITH,
HERBERT OSBORN, Chairman,
Trustees.

Report of the Committee on Necrology

April 11, 1936.

To the Ohio Academy of Science:

Your committee notes with regret the loss of the following members since the last annual meeting:

JANE M. DOREN, Columbus; joined the Academy in 1909, died in 1935 or 1936.

W. H. AIKEN, Cincinnati; joined the Academy in 1898, died October 31, 1935.

WILLIAM C. WERNER, Painesville; a charter member, joined in 1891, made a fellow in 1922, died 1935 or 1936.

THOMAS A. BONSER, Spokane, Wash.; member of the Ohio Academy of Science from 1896 to 1909, when he moved to Spokane; died August 4, 1935; native of Dayton, Ohio.

MRS. KATHARINE D. SHARP, London; joined the Academy in 1911, made a fellow in 1928; died September 19, 1935.

JOHN U. LLOYD, Cincinnati; charter member; made a fellow in 1920; died April 9, 1936, within ten days of being 87 years old.

Respectfully submitted,

JAMES P. PORTER,
Committee.

(Upon motion, the reading of the report carried with it a proper recognition of the work of these members.)

Report of the Membership Committee

April 11, 1936.

To the Ohio Academy of Science:

Your Committee on Membership has received and examined the following applications for membership in the Academy, found same in due form, dues for one year paid, and now recommend their election to full membership in the Academy, viz.:

1. ALBRIGHT, JOHN G., (F), 1906 E. 105th St., Cleveland.
2. ALEXOPOULOS, CONSTANTINE J., (B), Kent State University, Kent.
3. ANDERSON, AMOS C., (E), 137 N. Congress St., Athens.
4. BARR, DR. DANIEL R., (D), Grand Rapids, Ohio.
5. BAUMAN, HARRY, (A), 1091 Jefferson Ave., Akron.
6. BAYFIELD, E. G., (H), Ohio Agr. Exper. Sta., Wooster.
7. BERGSMARK, DANIEL R., (G), University of Cincinnati, Cincinnati.
8. BOND, CLYDE H., (G), R. F. D. No. 3, Quaker City.
9. BRILL, H. C. (H), Miami University, Oxford.
10. BUSCH, DANIEL A., (C), 2424 Sherwood Rd., Columbus.
11. DAVIDSON, HORACE B., (D), Hamilton Hall, O. S. U., Columbus.
12. DENO, RICHARD A., (A), State University, Bowling Green.
13. EBAUGH, DR. W. C., (H), Denison University, Granville.
14. EHLEERS, G. M., (C), University of Michigan, Ann Arbor, Mich.
15. GOSLIN, CHARLES R., (B), Lancaster.
16. HARROD, J. R., (H), 115 S. Johnson St., Ada.
17. HENDRICKSON, GORDON, (E), University of Cincinnati, Cincinnati.
18. HOPKINS, EVERETT H., (E), 711 N. Fountain Ave., Springfield.
19. HOROWITZ, MARTIN M. (A), 650 Carpenter St., Columbus.
20. JONES, DR. EDGAR P., (A), University of Akron, Akron.
21. KELLACEY, SISTER M. CELINE, (B), 2035 E. 79th St., Cleveland.
22. KELLEY, KENNETH L., (A), Kent State University, Kent.
23. LAMEY, CARL A., (C), Dept. of Geol., O. S. U., Columbus.
24. LANGLOIS, THOMAS H., (A), 3448 N. Broadway Place, Columbus.
25. LAWSON, CHESTER A., (A), Wittenberg College, Springfield.
26. PAPPENHAGEN, LOUIS A., (H), 705 W. State St., Alliance.
27. PARK, ORLANDO, (A), Northwestern University, Evanston, Ill.
28. RICHARDS, WILFRED G., (G), 337 Maple St., Oxford.
29. ROTHERMEL, MISS JULIA E., (A), Western College, Oxford.
30. SCHAEFER, PAUL E., (A), Dept. Z. and Ent., O. S. U., Columbus.
31. SCHOTT, RALPH G., (D), B. & Z. Bldg., O. S. U., Columbus.
32. SETON, SISTER ELIZABETH, (A), College of Mt. St. Joseph, Mt. St. Joseph.
33. SHADE, ERVIN H., (H), 681 Girard Ave., Marion.
34. SHANKS, ROYAL E., (B), North Bloomfield, Ohio.
35. SPANDEAU, H. M., (A and B), 97 Sherman Ave., Mansfield.
36. STRETF, RALPH F., (C), Miami University, Oxford.
37. VEEDER, MARTHA ANNA (H), Western College, Oxford.
38. WATT, LUCY J., (A, B and D), Western College, Oxford.
39. WILLIAMS, ARTHUR B., (A), 2717 Euclid Ave., Cleveland.
40. YUNCK, GEORGE F., (C), 706 Central Ave., Sandusky.
41. ZIMPFER, PAUL, (B), 1553 Moler Rd., Columbus.

Respectfully submitted,

K. G. A. BUSH, Chairman,
EUGENE VAN CLEEF,
SAMUEL ALLEN,
Committee.

NOTE: Letter in parenthesis after name indicates section of major interest.

Report of the Committee on Resolutions

April 11, 1936.

To the Ohio Academy of Science:

The Ohio Academy of Science wishes formally to express, for itself as an organization and for each of its members individually, appreciation to the authorities of the University of Toledo for the use of rooms and equipment in the conduct of meetings, and for the courtesies of its staff.

We desire to commend the accomplishments of the local committee which has provided excellent facilities for all our meetings and satisfactory arrangements for the personal comfort of visiting members at the 46th meeting.

F. C. WAITE,
Committee.

PRESIDENTIAL ADDRESS

THE CONCEPT OF NATURAL LAW IN GEOLOGY¹

WALTER H. BUCHER,

University of Cincinnati

Geology operates largely without the concept of "natural law." The speaker became keenly aware of this circumstance when, a number of years ago, he began his efforts to derive from rapidly accumulating knowledge concerning the geology of different parts of the earth generalizations designed to form a reliable foundation for reasoning concerning the dynamics of the earth's crust.² When he spoke of them as "laws of crustal deformation," he had to meet the objections of others and his own doubts. He had to view the procedure of geologic investigations in the light of the fundamental method of all science.

Some of the resulting reflections are presented here before men from many fields of science in the hope that they will lead to a clearer understanding of the nature of the geologist's work, and to that finer sympathy from which springs effective co-operation between men in different sciences upon which further progress depends in a large measure.

Geology is peculiarly dual in its aims: on the one hand it is concerned with what happened *once* at a *certain place*, in *individual* mines, mountains, regions. Interest that centers on individuals is *history*, not science.³ As a *science*, geology is concerned with the *typical* that finds expression in *generalizations*, whether they be called laws or something else. In his actual work, the geologist described the individual and attempts to grasp its meaning in terms of the typical. If you catch him unawares, he will tell you that he tries to "explain" the "facts" of geology in terms of the "laws of physics and chemistry." But the matter is actually much more complex.

For the purposes of the following discussion, we will do well to remind ourselves first of the essence of all scientific investigation and of the structure of science at large which results from it. Then we shall look at the scientific aspect of the geologist's work and the role which the concept of natural law plays in it.

Fairfield Osborn liked to tell the story "of the little redheaded fellow he accosted in the elevator one day. "Well, my boy," said Professor Osborn, "what do you like best in the museum?" The little tot, in sepulchral voice, answered "fossils."⁴ No doubt the circumstances justified the comic effect this answer produced. Yet the story sounds the funnier the less one knows about the mystery that attends the birth of a scientific career in a young mind. Every experienced worker knows of instances of children fascinated, without rhyme or reason, by

¹Presidential address read before the Ohio Academy of Science, at Toledo, on April 10, 1936. In the reading pages 191 to 192 were omitted. A number of minor changes have been made in the final manuscript.

²Walter H. Bucher, "The Deformation of the Earth's Crust. An Inductive Approach to the Problems of Diastrophism." Princeton University Press, 1933.

³Heinrich Rickert, "Die Grenzen der naturwissenschaftlichen Begriffsbildung," Tübingen, 1929, esp. pp. 217-237.

⁴Told by F. T. Davidson, president of the American Museum of Natural History. "Natural History," Vol. 37, 1936.

a group of objects in a museum. They come back with longing eyes and at last overcome their shyness and ask questions. They want to know.

What is it they want to know? Generally, above all, what things are called—names. Few aspects of science amuse the layman more than what he considers the child-like delight scientists take in cryptic, if not bombastic, nomenclature. There are not a few men of science, in fields less encumbered by verbiage, who are inclined to share this sentiment.

Those who are closer to the realities of the descriptive sciences know better. The plain fact is that apart from troublesome taxonomic tangles every scientific name is a code word for a group of natural laws as significant and dignified as those of any science. When the boy-who-wants-to-know is told that the crystal he is holding in his hand is quartz, he is actually told that any substance of that crystal form, luster, and fracture, always, by the inevitableness of experience which we call natural law, possesses a certain hardness, melting point, behavior towards acids, etc.⁵

If the shell he brought is *Polygyra*, he might be told, "Go back to the woods and collect a few shells just like this—they are common—but with the living animal still in it. You will find that animal possessing two pairs of tenacles, the larger ones each with an eye at the tip. You will find the mantle cavity lined with blood vessels, functioning as a lung. Dissolving the animal's head in potassium hydroxide, you will find a narrow ribbon beset with delicate teeth, many in a row, with specific shapes that can better be drawn than described, and so forth."

To the boy such predictions would seem like magic had he not been told early to accept the dry fact that all things have certain properties. The "properties" of objects are the "laws" of the descriptive sciences.

Conversely, it might be said that the "laws" of the so-called exact sciences are but expressions of "properties." When, over three hundred years ago, Kepler recognized, as a result of observations that extended over more than a decade, that the orbit of Mars is elliptical, he merely discovered a "property" of the planet's orbit. This is true even through his discovery required rare insight, being the result of keen abstractions from a very large number of observations concerning the position of the planet, and involving, furthermore, the assumption that the limited number of determinations was representative of an invariable form of the path.

In the same work (1609) in which he "described" the orbit of Mars, he published two of his bolder generalizations, the first of which stated that the orbits of all planets are ellipses. This, the first of the famous three laws of Kepler, has come down to us as a prototype of "laws." Yet it is purely descriptive.

It is true, it can be expressed in mathematical form. In that case we say, for instance, the paths of all planets are of the form $r = \frac{p}{1 - \epsilon \cos \theta}$ ⁶

⁵H. Poincaré. "The Value of Science," in "The Foundations of Science," the Science Press, 1929, p. 333.

⁶Where r and θ are the variables in polar co-ordinates, p is the "parameter"—the length of the normal erected in the focus measured to its intersection with the curve, and ϵ the "eccentricity" ($\epsilon = \frac{r_1}{d}$ where d is the distance from a given line, normal to the major axis). This is the general equation for all conic sections.

But that is no reason for calling it a "law" instead of a "property." Many of the "properties" found in the descriptive sciences can be expressed no less successfully in mathematical form. The shells of nautiloid cephalopods, for instance, grow in the form of a logarithmic spiral, in other words, assume an outline such that the advancing edge follows a path of the form $r = a^{\theta}$.

There is a better reason for calling some "properties" laws. It grows out of another aspect of scientific endeavor. The eager youngster in the museum asks not only, "What?" but also, "Why?" We are ready to tell him the properties of quartz and Polygyra. But then he asks, "Why is quartz so hard?" and "Why does a radula with numerous, closely set, small teeth go with a shell such as Polygyra?" This is a more serious matter. He asked for "knowledge" before, now he calls for "understanding."

What, precisely, do we mean when we say we "understand," in matters of science? In place of giving an abstract answer, let us picture to ourselves what happened when men learned to understand a simple fact of nature, for example, the rainbow.

First of all, this common meteorological phenomenon had to be observed carefully so that it meant more than a curved streak of colors in the sky. Its properties had to be observed and defined carefully, each of which has truly the dignity of a law, such as, "rainbows are segments of circles; the center of the rainbow lies on a straight line drawn through the sun and the observer's eye; a single rainbow is always violet on the inside and red on the outside;" and so forth. But even had he had all this knowledge, Aristotle would have been unable to understand even the simplest elements of the geometry of the rainbow. He ascribed it to the reflection of the sun's rays by the rain. He must have felt as unconvinced as we do about many so-called "explanations" of present day geology. Two hundred years later Ptolemy made a good start toward a study of refraction in what has been described as "the most remarkable experimental research of antiquity."⁸

But no one seems to have noted a possible connection with the rainbow. When the scientific spirit awoke again near the end of the Middle Ages, it was recognized that rainbows owed their origin in some way to refraction, perhaps combined with reflection. Real understanding had to await knowledge of the basic law. When W. Snell discovered (in 1621) the quantitative law of refraction, Descartes was quick to apply it to the problem of the rainbow. His calculated angle agreed with that observed. Men now "understood" the geometric laws concerning the rainbow as special cases of the broader law of refraction. The colors, however, remained a mystery. There were futile attempts at explanations, of course. We would call them working hypotheses today.

⁷Where, again, r and θ are the variables in polar co-ordinates and a is a constant.

See the chapter on logarithmic spirals (Ch. XI) in D'Arcy W. Thompson's fascinating book "On Growth and Form." Cambridge, 1917, pp. 493-586.

⁸G. Sarton. History of Science, Vol. 1, 1927, p. 274. Quoted from W. C. D. Dampier-Whetham, "A History of Science," 1931, p. 54.

Men might even have entertained "multiple hypotheses" in their search for a solution. The fact remains that no matter how large a number of multiple hypotheses was made, no solution could be found until the basic law was discovered, and cast into suitable form, upon which the solution depended. When Newton found the laws of dispersion, understanding came in a flash. "Understanding," then, as we use the word in science, consists in recognizing a specific law as the special case of a more general law.

Newton's demonstration that all three of Kepler's laws, apparently so different in content, are merely the geometrical implications of an abstraction of by far more general character, is perhaps the most illustrious example of an intrinsically great feat of understanding.⁹

Quite instinctively, certainly without any particular method, we speak of "laws" when we recognize generalizations that are fraught with possibilities of understanding—in contrast to those generalizations which establish relationships to be understood—the properties. Thus we speak of Osborn's law of adaptive radiation in biology, of Ferrel's law in meteorology, of Rosenbusch's law in petrography. The more general a law, the greater its resolving power. In order to be general, it must be abstract. The more abstract it is, the more amenable it is to mathematical treatment—the more exact is the form in which it can be stated.

The sciences that face the objects of experience in their full complexity—such as the plants, animals, rocks, topography, weather—find the mathematical language inadequate to their task. The curves defining the shape of a trilobite or of granite intrusive, like the flow lines of a weir in a river or of the air on a weather map, defy mathematical analysis. Accurate description of reality seen in nature and in experiment form the accumulated store of scientific knowledge in these sciences. From it there arise, through judicious generalizations, "specific laws" that give us the first sense of order in the concrete aspect of complex reality. Back of them, revealed by greater and greater abstraction from reality, we distinguish the more and more general laws of chemistry, physics, mechanics, electrodynamics, mathematics. This is the familiar picture of the hierarchy of the sciences. It is repeated in the structure of every branch of science.

In geology we see geophysicists, students of geotectonics, regional geologists, stratigraphers, petrographers, mineralogists gather observations that are to lead ultimately to an understanding of the complicated spectacle of the earth. Like horizontal strata of decreasing complexity, lie the levels at which these men are working, each forming at least part of the foundation for the work of those above it.

At each level laws must be formulated without which understanding is impossible at the higher levels of complexity. This is the picture the geologist must keep before him if he is to do his best work and derive the deepest satisfaction from it.

⁹The proof with the mathematical tools that Newton had at his disposal was a very great achievement indeed. In modern vector notation the proof is quite simple and occupies not more than two pages for all three laws.

See Louis Brand, "Vectorial Mechanics." New York, 1930, pp. 401-403.

Let us now see how this works out in practice. Take the case of the igneous rocks. Observations led early to the definition of numerous types and to attempts at classification. Mineral composition and texture were studied comparatively. Here, as always, comparative studies led to generalizations which were more than mere properties of types, generalizations that had the character of the empirical laws. "Nephelite-bearing rocks are free from quartz" is one. Rosenbusch's law concerning the typical sequence of (final) crystallization, from basic to acid minerals, is another.

Not until such laws were formulated could any serious desire for explanations, for "understanding," arise. Before, it would probably have seemed rather silly to ask, "Why is a basalt constituted the way it is?" One might as well ask, "Why do radulas of the *Polygyra* type go with the shells that characterize that genus?" That is the way it is—that is all.

It would certainly have been futile to go to the classical chemistry of the last century for an answer. No number of multiple hypotheses could have led to the trail of understanding; because understanding could not even be conceived until physical chemistry had reached the state of the phase rule.

But even after the basic concepts had been created, much work had to be done before an understanding of the characteristics of mineral associations in igneous rocks became possible. The level between the abstract theory and the complex reality of the rocks had to be filled by experiment on the properties of silicate melts. Investigations in that field are expensive. Industry was slow in entering that no-man's land. When the geophysical laboratory of the Carnegie Institute of Washington was established, it undertook to fill the gap.¹⁰ The Kaiser Wilhelm Institut für Silicatiforschung in Berlin-Dahlem was modeled after it. For over three decades the work has gone on. One by one the empirical laws of petrography are becoming intelligible, if not fully understood, in the light of the properties of silicate melts. Thus formulation of empirical laws, systematic exploration of artificially simplified systems: those are the steps from which springs the understanding of reality which is the ultimate aim of science.

Let us turn to another illustration. In a sense, mineralogic-petrographic studies on igneous rocks are not typical of geologic work. The units with which they deal can be taken into the laboratory, weighed, studied under the microscope, analyzed chemically.

Geologic investigations in the strict sense of the term, on the other hand, deal with sizable parts of the earth's crust. While these are, of course, small compared with the objects studied by the astronomer, they have the disadvantage of being right up against us. They are vast compared to man's size. The amount of physical labor and time consumed in merely traversing the objects of study looms large. The methods of the surveyor and cartographer and graphic representations

¹⁰It is instructive to read the diverse suggestions which were received by the advisory committee on geophysics from outstanding geologists and geophysicists, at the founding of the Carnegie Institution (Year Book No. 1, 1902, pp. 44-70) and contrast with them the purposeful limitation of the work which was ultimately adopted and which has led to such uniquely valuable results.

of diverse kinds must be used to record the knowledge gained. In typical cases the work of several men and of several field seasons is required to furnish a reasonably accurate description of one object of study, one individual, if you please.

Take the case of the oil-bearing strata of the Green River shale—sediments of a long extinct lake in western Colorado, Wyoming, and Utah. In order merely to describe this stratigraphic individual adequately, it is necessary to traverse along as many lines as possible the 25,000 square miles covered by these sediments; to study the variations in the sediments, especially the near-shore phases; to measure the rhythmic lamination of the sediments, which is such a conspicuous feature of the formation, throughout the 2,000 feet of thickness and to compare the results for as many sections as possible; to look for and study carefully zones with significant minerals, such as a rather unique analcite bed and more numerous layers of other peculiar minerals; to study the nature of the organic material, chemically and above all with the microscope and microtome; to make collections, as exhaustive as possible, of the fossil leaves, insects, fishes, for which the beds are famous and to establish the taxonomic identity of the microscopic and megascopic forms found. Vast labors in the field, in the laboratory, the herbarium, and museum by a score or more of men were needed to complete, in the course of years, a reasonably accurate description of this formation.

The result of all this labor is the description of a *single individual*, one body of deposits. No laws can be derived from this individual. But laws are needed to understand its properties.

Take the most conspicuous property of these beds, the fine lamination that runs with mathematical accuracy through every microscopic section, in endless alternations of pairs of layers, measured in tenths of millimeters, one chiefly organic matter, the other largely inorganic. What does it mean?

Many possible explanations come to mind. The geologist, more than other men of science, must work with multiple hypotheses. For understanding, the geologist turns to limnology. One "law" of limnology suggests an explanation: the plancton of lakes reaches annually a relatively short peak dropping to a minimum for the rest of the year. The microscope shows that the organic matter of the laminae consists of plancton. Here is a possible answer. Another "law" of limnology¹¹ points to the same answer: the deposits at the bottoms of modern lakes in moist climates show similar alternations of organic (planctonic) and inorganic laminae.

The Green River beds represent part of the Eocene period. Radioactive minerals have furnished data which give a rough estimate of the length of the Eocene period. This can be compared with the length of time represented by the fraction of it comprised in the Green River shales, computed on the assumption that each pair of laminae records

¹¹B. W. Perfiliew. "Das Gesetz der Periodizität der Schlamm-Bildung und die Tiefgewässer-Bohrung." Verh. Intern. Verein. f. Limnologie, 1931, Vol. 5, pp. 298-306. (Known to the writer at present only through a review in Bot. Zentralbl., Vol. 164, p. 98, 1931, to which Dr. Th. Just called the writer's attention.)

one year. The figure found, 6,000,000 years, compares favorably. One more test suggests itself. The thickness of the pairs of laminae is variable. If they represent deposits of one year each, their varying thickness must somehow be connected with fluctuations of climate. A "law" of climatology proves useful: climatic variations proceed in complex curves in which definite cycles are recognizable. When plotted, the laminae of the Green River shale reveal the same cycles.

Thus each new investigation points in the same direction: we are getting nearer and nearer to a satisfactory understanding.¹²

This case is typical of geological work. The empirical laws formulated in the course of studies on living environments and processes—although not labeled as such—form the means of understanding the properties of an individual of stratigraphy—the Green River lake beds.

But there are other famous fossil lake beds—like those of Florissant in Colorado or of Oeningen in Switzerland and many others, little studied. As one by one they are described and analyzed, common properties will be recognized and formulated. There are already in existence interesting discussions of the "Criteria" for lacustrine sediments.

The field of structural geology represents a higher level of complexity in geologic studies. In certain belts the strata of the earth's crust lie deformed: broken by fractures, or crushed along shear zones, bent into folds and thrust one on top of the other along thrust planes. Here the difficulties in the way of study are multiplied. Even if the earth's crust were transparent and the actual features of the deformation could actually be seen to the depth of a mile or two, the mere task of recording, in intelligible manner, the three-dimensional pattern of a folded mountain chain would present great difficulties. With only the surface accessible to the eye and most of it concealed by vegetation and mantle rock, the unraveling of the structure of such regions as the Alps or the Scottish Highlands represents a herculean task, for the body as well as the mind.

While the anatomist can produce hundreds of sections with his microtome in a fraction of an afternoon, it takes years of topographic surveying and decades of geologic mapping, each man refining and correcting the observations of his predecessors, before a series of reasonably accurate cross-sections can be produced through such a region as the Swiss Alps or the folded Appalachians. Here again, then, the descriptions of individuals is still, by force of circumstances, the dominant occupation of the geologist.

Nevertheless, it is just in this field, that the search for typical patterns, for laws of deformations began early. Types of folds and patterns of fractures were early recognized and given names. The practical importance of many structural features in mining and prospecting led to a high development of the formal aspects of rock deformation. As early as 1878 Albert Heim's "*Untersuchungen uber den Mechanismus*

¹²I have quoted from a series of classical investigations by W. H. Bradley, of the U. S. Geological Survey. See especially, "The Varves and Climate of the Green River Epoch," U. S. G. S., Prof. Paper 158, 1929, pp. 87-110; "Origin and microfossils of the oil shale of the Green River Formation of Colorado and Utah," *ibid.*, Prof. Paper 168, 1931, 58 pp. and 28 plates.

der Gebirgs Bildung" brought exemplary precise formulations of valid generalizations.

But understanding of the structural facts in terms of more basic laws has barely begun. For classical physics, proceeding along strictly inductive lines, had limited itself at first almost entirely to the simplest aspects of the deformation of bodies, which are below the elastic limit, where relatively simple equations can be tested by crucial experiment. Valiant attempts were made by geophysicists to attack the problems of rock deformation with the inadequate tools of the classical theory of elasticity. Papers were written that were learned but not convincing. Understanding could not be expected until physicists ventured forth from the abstract field of simplest cases into the realities of the world of bodies at large. This time industry has filled the gap with its practical demands, and a new empirical science, the physics of materials, has come into existence. Such basic properties as plasticity, strength, rigidity, brittleness are being studied exhaustively. Empirical laws are being cast into mathematical form. Fracture patterns and other forms of deformation are being studied and analyzed. In that way laws of behavior of materials are being formulated out of which ultimately will come a true insight into the nature of geological structures.

One phase of modern studies of granite massifs may serve as a concrete illustration. At the time when the merciless inflation of the after-war period crippled the activities of many German geologists by making distant traveling impossible, Dr. Hans Cloos at Breslau took a devoted body of students into the numerous granite quarries of the nearby mountains of Silesia and carried on systematic studies of the innumerable fractures that cut every granite body in nature.¹³ Tens of thousands of readings giving the attitude in space of all important fracture surfaces observed were plotted graphically. Soon definite systems of fractures were recognized that run uniformly through a granite mass: fracture aligned at right angles to the strike; longitudinal fractures; conjugate shearing planes; and pinnate fractures along the contacts. This assemblage of fractures has since been found to be practically universally present in intrusive bodies of granite.¹⁴ Their presence constitutes empirical laws of great value.

When these empirical laws had been established, Dr. Cloos undertook to supply the knowledge that was needed for understanding. In a series of ingenious laboratory experiments, he has attempted to reproduce the essential aspects of orogenic deformation. Reasoning in terms of factors of similitude, he used a mixture of water and clay for his experiments, a substance yielding to gravity and yet of such coherence as to fracture after the fashion of such solids as granite. When he showed his extraordinary results at the next International Congress,

¹³He carried out near his home investigations inspired in pre-war days, by his careful studies of beautifully exposed granite regions in the deserts of Southwest Africa.

¹⁴For a bibliography of papers by Cloos and his collaborators, see Robert Balk, "Primary Structure of Granite Massives," *Bull. Geol. Soc. America*, Vol. 36, 1925, pp. 695-696. (A larger paper by the same author, entitled "Structural Behavior of Igneous Rocks," will soon appear as one of the *Memoirs of the Geological Society of America*.)

more than one geologist shrugged his shoulders: "What can one learn from wet mud about granite?"¹⁵

The highest degree of complexity is reached when the earth as a whole becomes the object of study—in what is now widely called geotectonics. Here it is not the details of structure of individual mountain ranges, but the pattern of folded mountains on the face of the earth as a whole that demands attention; not the relations of one plateau to another, but that of the continental platforms to each other and to the oceanic floors; not the events of volcanic outbursts in one region, but the connection that exists between belts of volcanism and belts of deformation; and so forth.

To the complexities of three-dimensional structure, the time element is added as the fourth dimension. The geologist's intricate and still very crude methods of relative timing must be used to determine whether epochs of folding are short, spasmodic events, or long drawn out processes; whether mountain folding takes place simultaneously in many parts of the earth followed by periods of quiet, or whether some folding has been going on somewhere on earth throughout geologic time; whether epochs of mountain folding coincide with times when continents became submerged by a rising sea level, or with times of emergence—and so forth.

In the four volumes of "The Face of the Earth," a work of rare compass, depth and beauty,¹⁶ the product of thirty years,¹⁷ Eduard Suess has laid the foundation for all such inductive studies concerning the deformation of the earth's crust. In this work the masterful picture of the then available knowledge of the structure of the whole face of the earth, covering over 2,700 pages, culminates in a few chapters of "Analyses" and "Hypotheses" of only 138 pages¹⁸ which grip by their moderation, the tentative and cautious tone of their interpretations. Fertilized by the fervent enthusiasm and the almost inexhaustible riches of this work, structural analysis has since been carried systematically into most parts of the world. The detailed literature on regional tectonics has grown beyond the grasp even of a genius. But the growing number of authentic summary accounts and of tectonic analyses of limited areas, on the other hand, are making accessible more and more the generalized results from many parts of the earth. From them gradually broader generalizations are being derived that hold good everywhere today and will stand the test of future observations, generalizations that are true "laws." A few such laws were established long ago, as, for

¹⁵The following papers deal with tektonic experiments of this type in general: H. Cloos. "Experimente zur inneren Tektonik." *Centralbl. f. Min. Abt. B*, 1928, pp. 609-621; "Künstliche Gebirge," I, *Natur und Museum*, 1929, pp. 225-243; II, *ibid*, 1930, pp. 258-269; "Zur experimentellen Tektonik," *Naturwissenschaften*, vol. 18, 1930, pp. 741-747; "Zur experimentellen Tektonik," *Geol. Rundschau*, 1930, pp. 353-367; "Zur experimentellen Tektonik," *Naturwissenschaften*, vol. 19, 1931, pp. 242.

¹⁶In his epilogue to the French Edition, Termier has called this work "bien un poème, dans le sens complet de ce mot splendide qui veut dire création." "La Face de la Terre," vol. 3, pt. 4, 1918, p. 1713.

¹⁷Edward Suess, "Das Antlitz der Erde," Vol. I, 1883; Vol. II, 1888; Vol. III, pt. 1, 1901; Vol. III, pt. 2, 1909.

¹⁸In the English Edition of Sollas and Sollas.

instance, Elie de Beaumont's law of the episodic character of orogeneses (1829); Godwin-Austen's law of the tendency of posthumous folds to trend parallel with the lines of earlier folding (1856); Hall's law of the coincidence of belts of folding with belts of abnormally thick sediments (1859).

Ten years after Suess' death, Stille published his "Grundfragen der vergleichenden Tektonik."¹⁹ The title of this remarkable work makes effective use of the expression "Comparative tectonics" and the text culminates in the formulation of a "law," Stille's "orogenes Zeitgesetz."²⁰ It is a broad generalization based on two properties of orogenic movements concerning their incidence in time. It is a general law of broad resolving power. The writer believes it to be valid. But geologists are by no means agreed that the two properties on which the law is based are really general and essential. Such a generalization can hardly be called more than an "opinion," until it can be shown to rest on a valid basis. On the whole we are not ready to formulate such broad laws. The first task is to crystallize knowledge concerning the observable properties of the structure of the earth's crust. Stille's book is primarily devoted to this task as far as the time element in orogenesis (and epeirogenesis) is concerned. The speaker has attempted to extend this work to other properties. On the strength of the convictions set forth in this address he spoke of them as "laws," *i. e.*, "specific laws" of crustal deformation, from which ultimately such "general laws" as Stille's will be derived. He might have listed his "specific laws" as "properties." He preferred the more challenging "law." The word he could not use, suggested to him more than once, was "theses." "Too much of the geotectonic literature of the past was concerned with the theses of men rather than with laws of nature."²¹

This, then, is the essence of all geologic work:

1. Not to be satisfied with the accumulation of facts alone, but to draw from them, at every opportunity, all possible generalizations. In other words, to search for the general properties, the "specific laws" in the reality with which we deal, and ultimately for such "general laws" as can be safely formulated.

2. To seek understanding of the empirical laws thus found by studying the findings of workers in the nearest level of complexity. For the geologist, that means stepping from the records of the past to the experiences of the present; from the properties of vast bodies to those of small units of the laboratory; from the complex systems of nature, to simpler systems capable of analysis. It means oceanography, limnology, hydrology, the physics of materials, the physical chemistry of silicate melts, and so forth, not simply elementary textbooks of chemistry or physics.

Neither of these two points is followed as widely as one should expect. As to the first, a multitude of facts is still published with little or no evidence of thought concerning their broader bearings. As to the second, uncontrolled speculation still too often takes the place of that

¹⁹Berlin, 1924 (Gebr. Borntraeger).

²⁰Loc. cit., pp. 44-45.

²¹Walter H. Bucher, "The deformation of the earth's crust." Princeton, 1933, p. VII (Preface).

systematic searching for an adequate foundation for understanding which is needed. When we try to understand the Permian glaciation, we still invoke movements of the continents or of the poles (or both), instead of instigating that prolonged systematic research by competent meteorologists which alone can make sure that wide areal glaciation down to sea-level is impossible in equatorial latitudes; we use similar speculations when we speak of the existence during the geologic past of higher vegetation near the poles,²² without having brought about investigations needed to decide if trees can grow where the night and day last half a year each; we demand vertical uplift of the continental shelves of nearly two miles to "explain" the submarine valleys before having placed the problem into the hands of experienced hydrologists familiar with the complex currents set up by the tides, and so forth.

Speculation that does not lead directly to further search for facts and laws is idle. The joy of understanding arises from reasoning, not from guessing; from the purposeful grouping of general facts, not from the mere play of the imagination.

Two things remain to be said. One refers to the human side of this task. The other points to the future outlook.

For the human side let us turn back once more to the boy-who-wanted-to-know in the museum. Let us assume that his enthusiasm held out through his high school years—we are optimists, you see. He has pushed through as fast as possible, impatient of any delay, to that field of science which at the time satisfied his fancy. He has become a geologist. The more he learns about the strata and structures, the less he is satisfied with the mere description of "facts." He turns to basic works on limnology, hydrology, physics of materials. And now he finds much that he cannot read. Not only a strange terminology, but the unfamiliar concepts and lines of reasoning of the basic sciences: physical chemistry, vector mathematics, statistics, etc. He wishes he had become a mathematician first, then a physicist, and then a chemist. He looks with envy upon those who work in the abstract fields of artificial simplicity, where knowledge is exact and reasoning rigorous. His own problems seem muddled, his own mind inadequate.

But when he seeks co-operation from the fortunate ones who are mathematicians and physicists, he makes a discovery. Just as he, in the typical case, at his stage of life cannot spend the energy and time necessary to acquire a working knowledge of the mental tools of the basic sciences, so the workers in the abstract sciences find the task too great to acquire the perspective over the intricacies of unabstracted reality without which creative work is impossible. Moreover, he who is accustomed to the "linear order of thought which is necessarily cultivated in . . . mathematics" finds it distasteful, if not difficult, to acquire "the habit of parallel . . ." or "complex thought," as T. C. Chamberlin²³

²²Since this was written, coniferous wood of araucarian type has been reported, found together with leaf impressions of cycadophytes in the Upper Triassic or Jurassic florule associated with coal, which was collected in south latitude 86°–58', i. e., within 3 degrees of the South Pole. Wm. C. Darrah, "Antarctic fossil plants," *Science*, Vol. 83, 1936, pp. 390–391.

²³T. C. Chamberlin, "The Method of Multiple Working Hypotheses," *Jour. Geol.*, Vol. 39, 1931, p. 164. (Reprinted from the original in *Jour. Geol.*, Vol. 5, 1897, pp. 837–848.)

once called it, in which a multitude of interrelated properties must be visualized and weighed as parts of an integral whole.

The recognition of this difference is wholesome. Every geologist needs such an experience to find the right pride in his work. The worker in the complex levels of science is the explorer, the man from the basic sciences the guide. One derives his significance from the other, and both derive the sense of dignity in their calling from the joint goal which is an ordered insight into complex reality.

As to the outlook for the future: I have spoken so far of two steps that enter into the mental process of the geologist. But there are really three:

First comes: *Analysis*, "*re-solving*" the complexity of geological reality into its constituent, essential elements of orderly recurrence, formulated as generalizations which we call "properties" or "specific laws."

Second: *Interpretation*, "*translating*" these "properties" or "specific laws" into the terms of the more "general laws" of the basic sciences. This constitutes "understanding."

The third is: *Synthesis*, "*putting together*" again, collecting in our consciousness the numerous threads of understanding into one adequate perspective of nature as we see it in its entirety.

"Analysis" is in full swing. "Interpretation, and with it "understanding," is growing, as laws are being formulated in the fields of investigation that lie between geology and the basic sciences.

But in the larger aspects of geology the final synthesis which is to give us a satisfying, logically consistent and coherent picture of the earth and the forces that have formed and are forming it, is a hope for the future. It will be brought about by the growth of a tendency which is taking form now. Analysis produces specialists; the growing need for synthesis will produce encyclopedists. H. G. Wells put it this way: "The world, if all goes well with it, will consist very largely of specialists, who know every detail about and every relationship of something, and of people . . . who will know everything in outline and in correlation. Specialism and encyclopedism are necessary correlatives."

Analysis and interpretation require the field and the laboratory. Synthesis is done in the philosopher's study. Most geologists, and for that matter most scientists at large, mistrust the man who studies not nature, but natural laws. His work looks like the boring and hoarding of the bookworm. Most scientists are still unaware of the difference between unimaginative compiling, the cataloguing of facts, and the creative power that is required for all true synthesis. Yet it is such synthesis alone which can make us fully aware of nature. For, to see the work of many in one perspective, to realize the common bond of natural law that permeates all our experiences of nature, means to realize the "internal harmony of the world" which, as Poincaré pointed out repeatedly,²⁴ is "The only true objective reality," the ultimate goal of all science.

²⁴H. Poincaré in "The Foundation of Science," The Science Press, 1929, e. g., pp. 207, 209.